Diviner Observations of Pure Plagioclase Regions on the Moon as Identified by SELENE and M3

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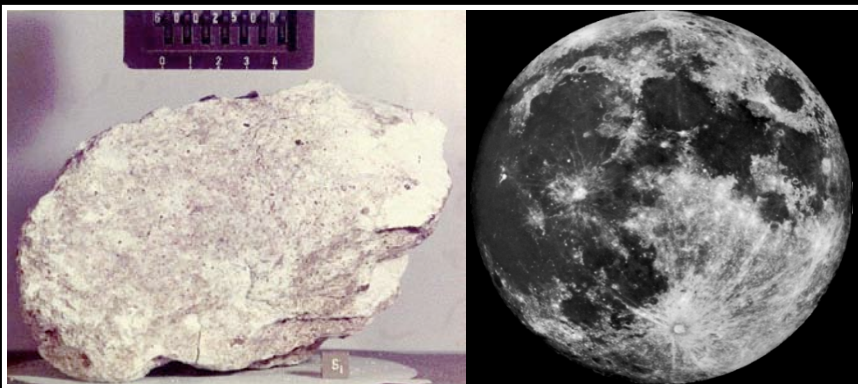
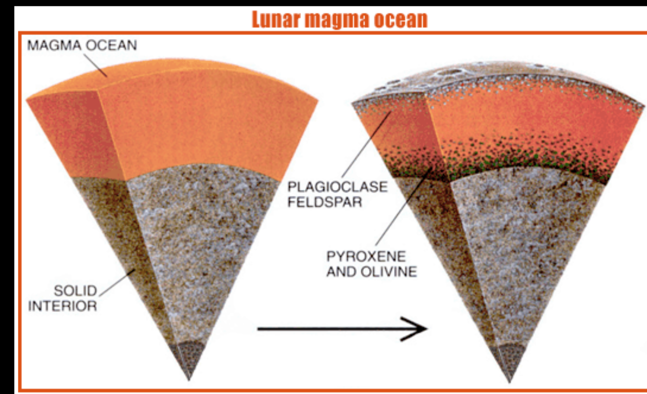
[1]Brown University, [2]University of California, Los Angeles, [3]Jet Propulsion Laboratory, [4]Oxford University

Apollo Background: Plagioclase on the Moon



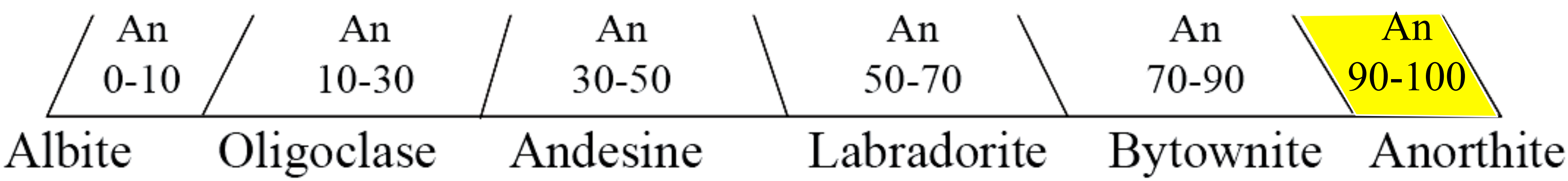


1) Apollo Anorthosite ✓

> 90 vol. % Plagioclase

2) Lunar Magma Ocean ✓

* collected from a small portion of the nearside highland regions

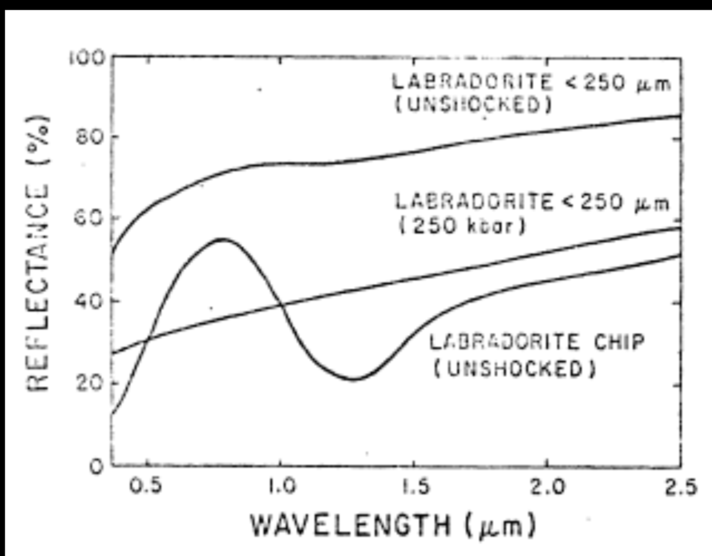


Plagioclase Solid Solution Series

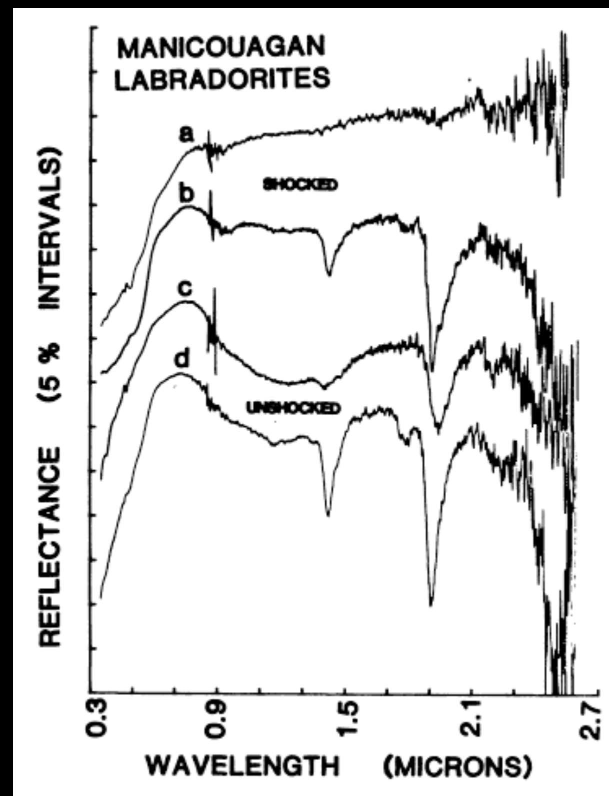
VNIR Background: Plagioclase

- NIR spectra of plagioclase with trace amounts of iron (>0.1 wt% FeO) exhibit a broad absorption band centered near 1.25 μm owing to the electronic transitions of minor amounts of Fe^{2+}.

- Band broadens and weakens in crystalline plagioclase that is shocked at pressures approaching the threshold for diaplectic glass, and disappears with development of maskelynite.

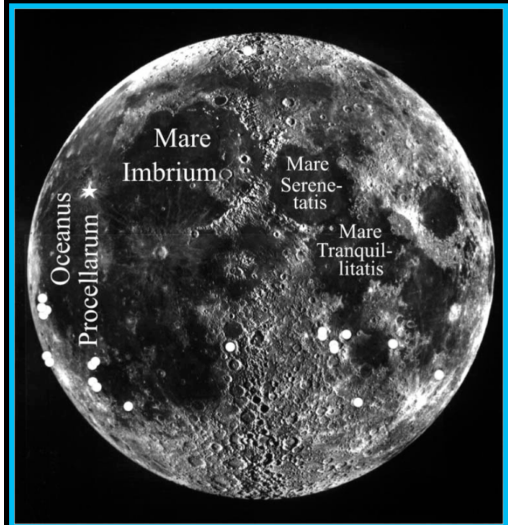


Adams and Gibbons, 1979



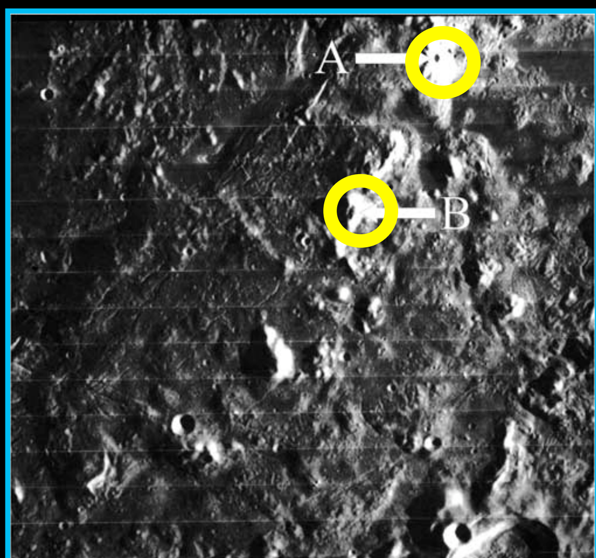
Bruckenthal and Pieters, 1984

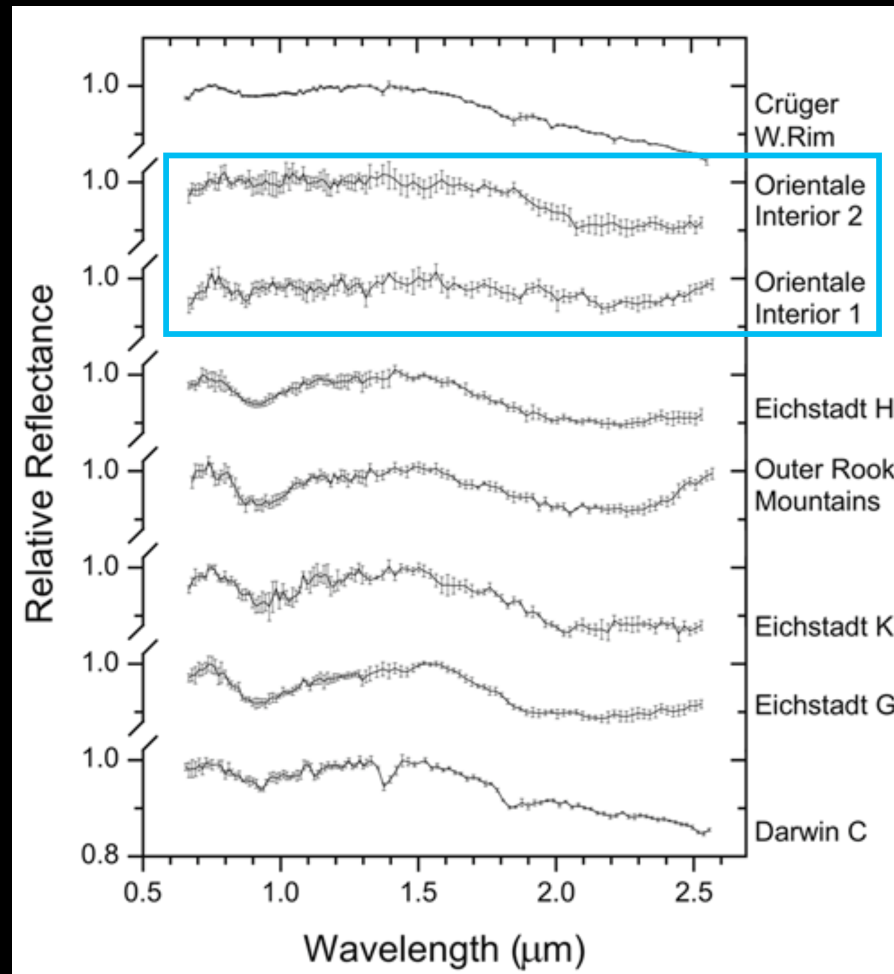
VNIR Background: Plagioclase on the Moon



- Inner Rook spectra exhibit no 1 μm absorption bands (no mafics).

- Composed almost entirely of plagioclase feldspar (shocked) with <5% pyroxene.

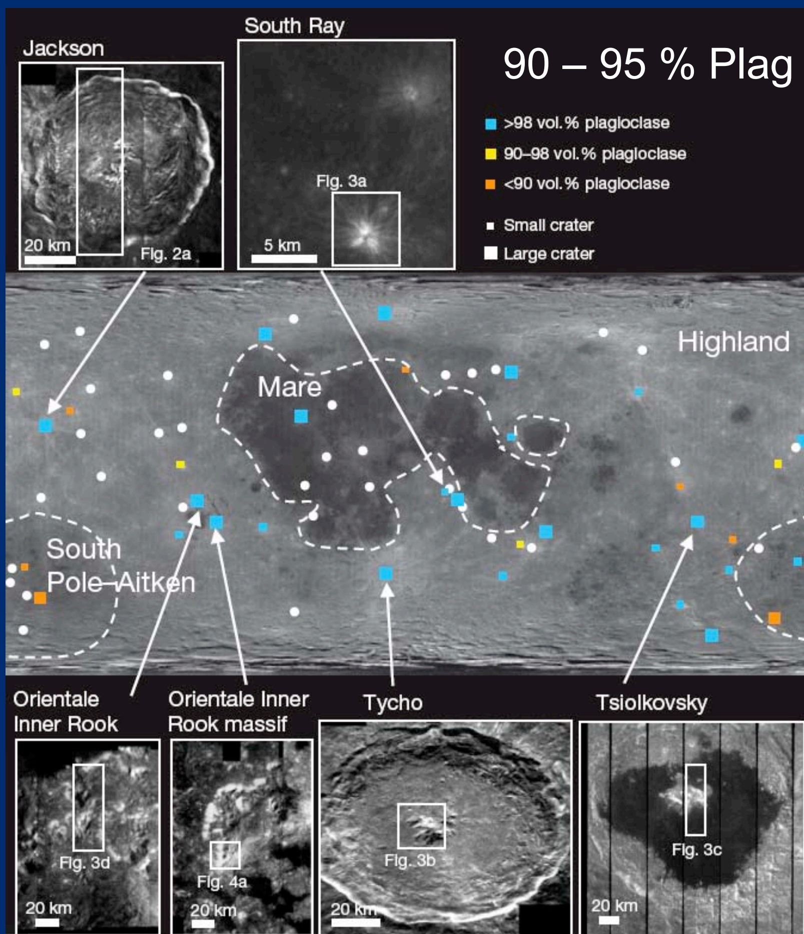




Hawke et al., 2003

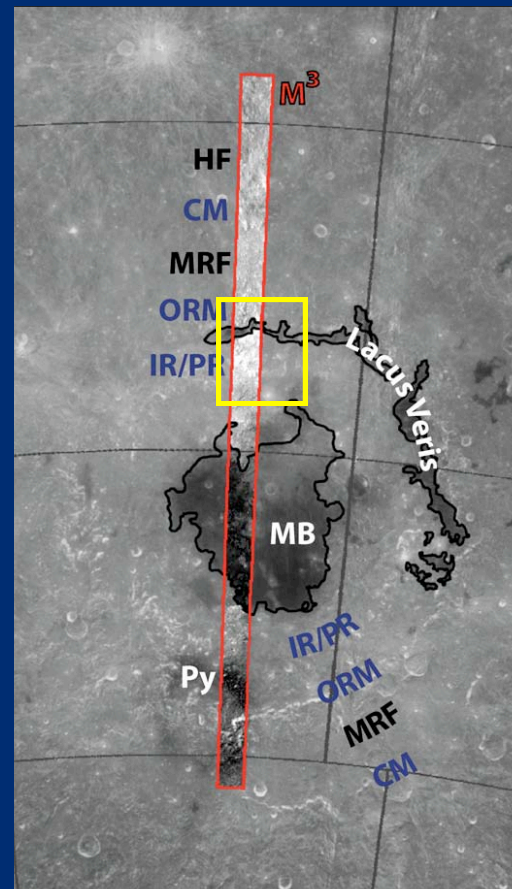
VNIR Background: Plagioclase on the Moon

SELENE - SP and MI



Ohtake et al., 2009

M^3



Pieters et al., 2009

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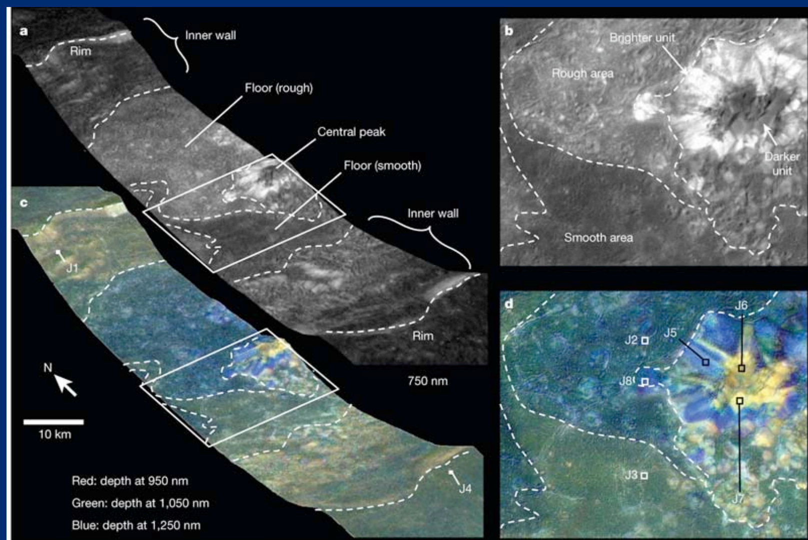

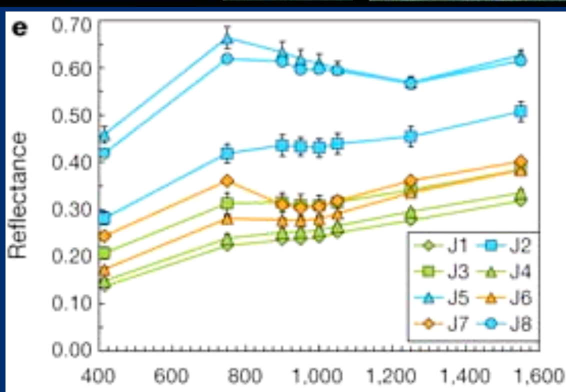

Ohtake et al., 2009

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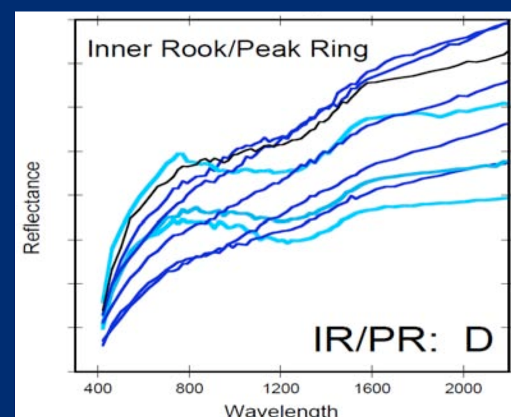
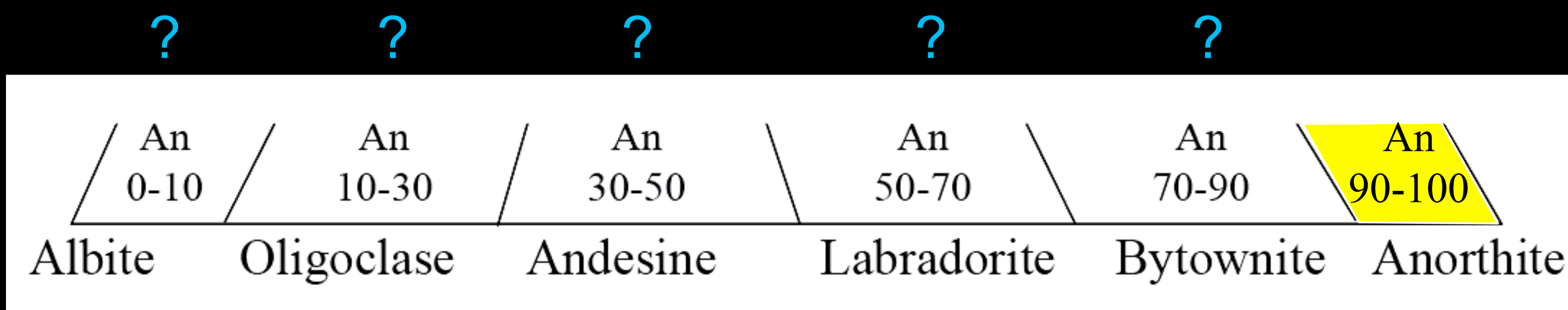


Pieters et al., 2009

NIR data confirm the presence of widespread, crystalline, “pure” plagioclase on the Moon

Outstanding Question: Plagioclase on the Moon

- What is the compositional diversity of plagioclase (An #) in the lunar highlands?



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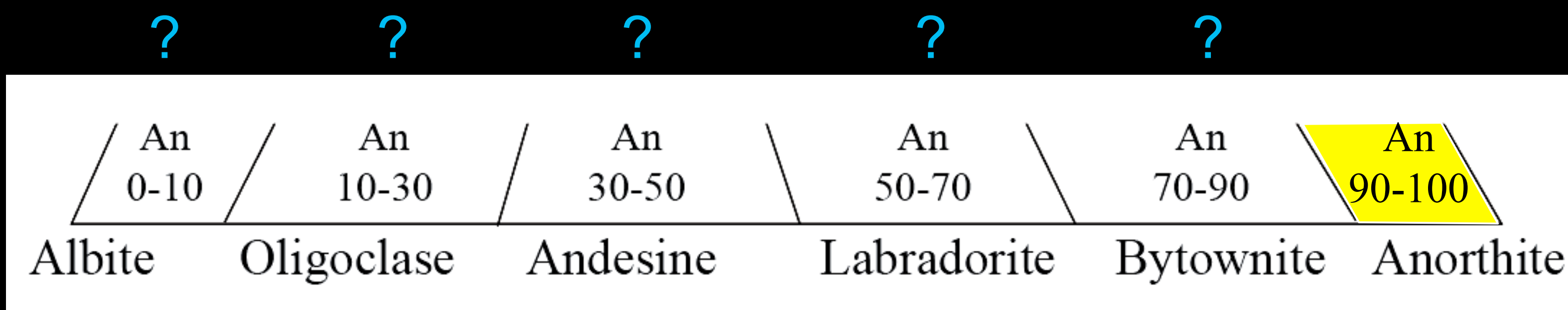

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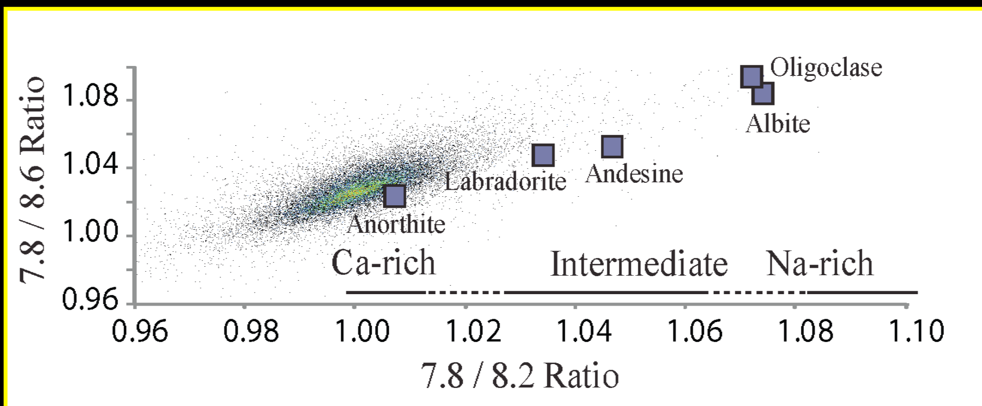
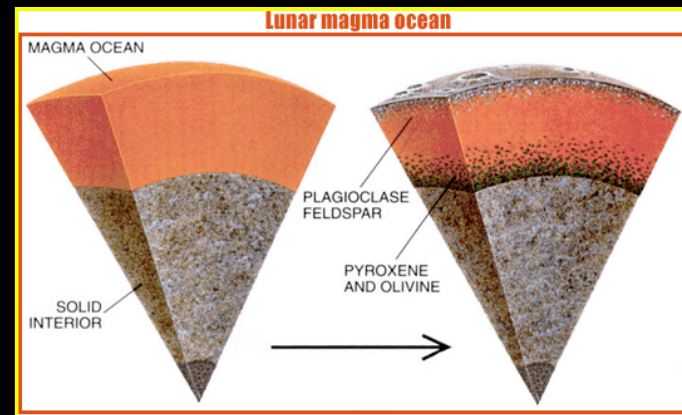
- Thermal Infrared (TIR) spectra of plagioclase minerals are diagnostic of composition (An #) and have been extensively studied in mineral mixtures and rocks in the laboratory. *e.g. Nash and Salisbury, 1991; Ruff, 1998, Wyatt et al., 2000; Milam et al., 2007*

- Applications to Mars orbital and surface remote sensing data (TES & Mini-TES). *e.g. Christensen et al., 2000, 2004; Bandfield et al., 2000; Rogers et al., 2007*

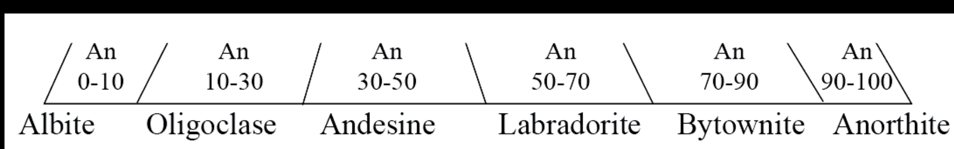
Diviner Plagioclase Research Objectives

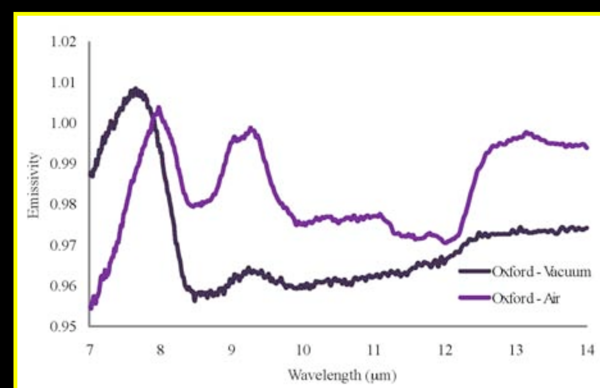
- Target pure plagioclase regions on the Moon as identified by Selene SP and Chandrayaan M^3 with LRO Diviner data to constrain plagioclase compositions (An #) and examine implications for a lunar magma ocean.



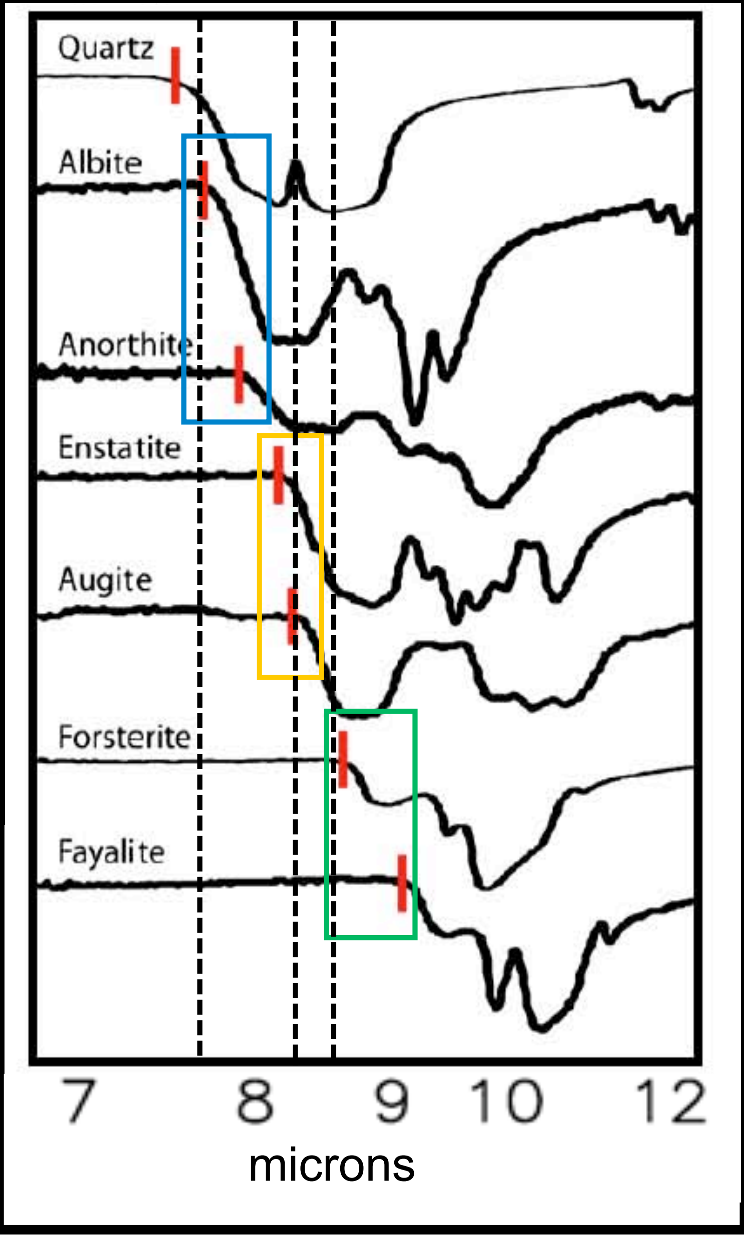


- Collect new laboratory TIR emission spectra of the plagioclase solid solution series under lunar-like conditions.





Background: Diviner TIR Spectral Bands



Diviner's 3 spectral bands designed to map Christiansen Feature (CF)

⇒ CF is an emission maximum and is an indicator of composition

The wavelength position of the CF is diagnostic of composition and changes with the change in bond strength and molecular geometry associated with changing mineralogy

Olivine and **Pyroxene**
High Fe and Mg = CF Long Wavelengths

Plagioclase
Low Fe and Mg = CF Short Wavelengths

UCLA JPL STONY BROOK BROWN W NASA

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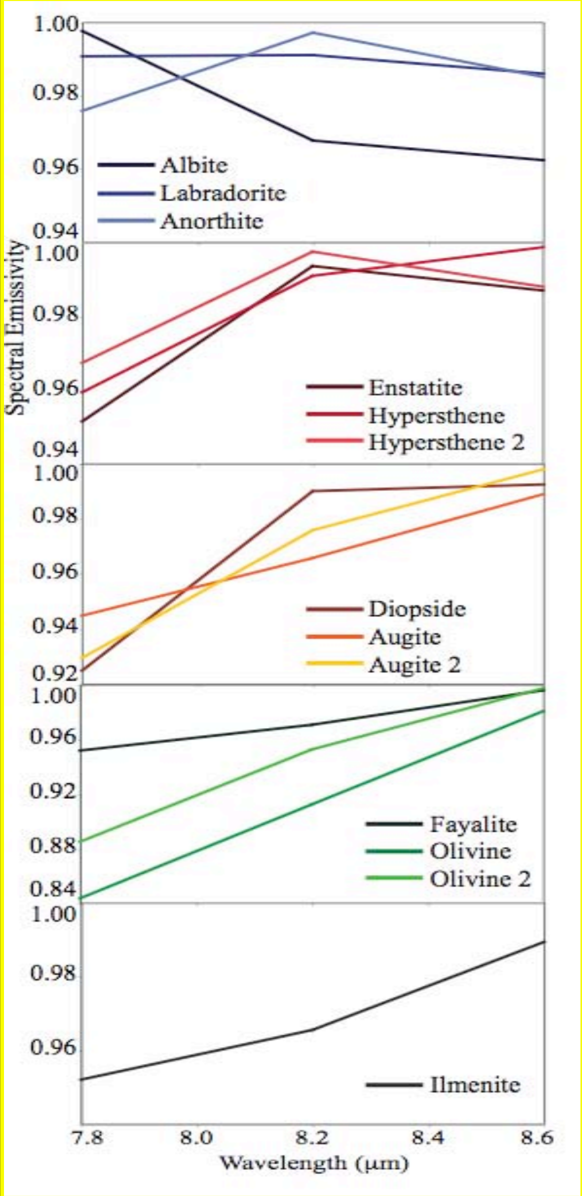
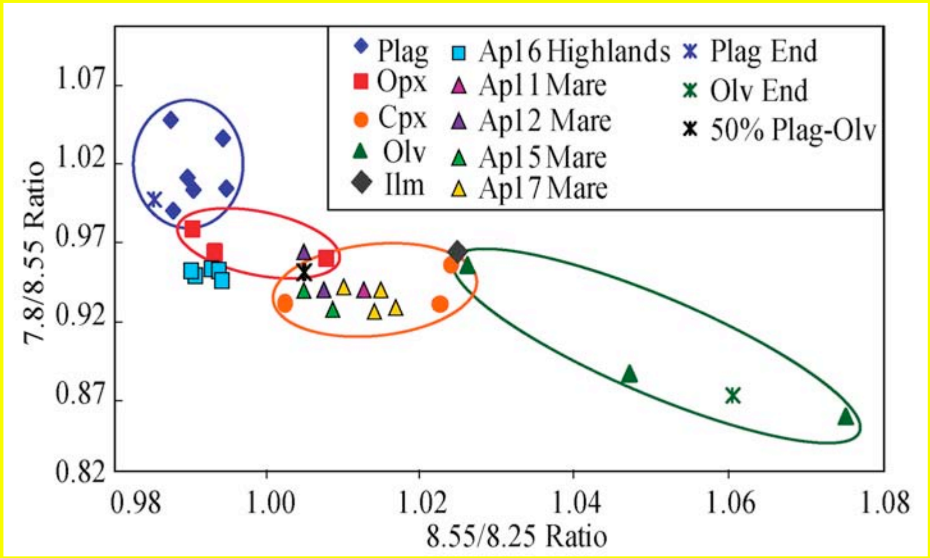




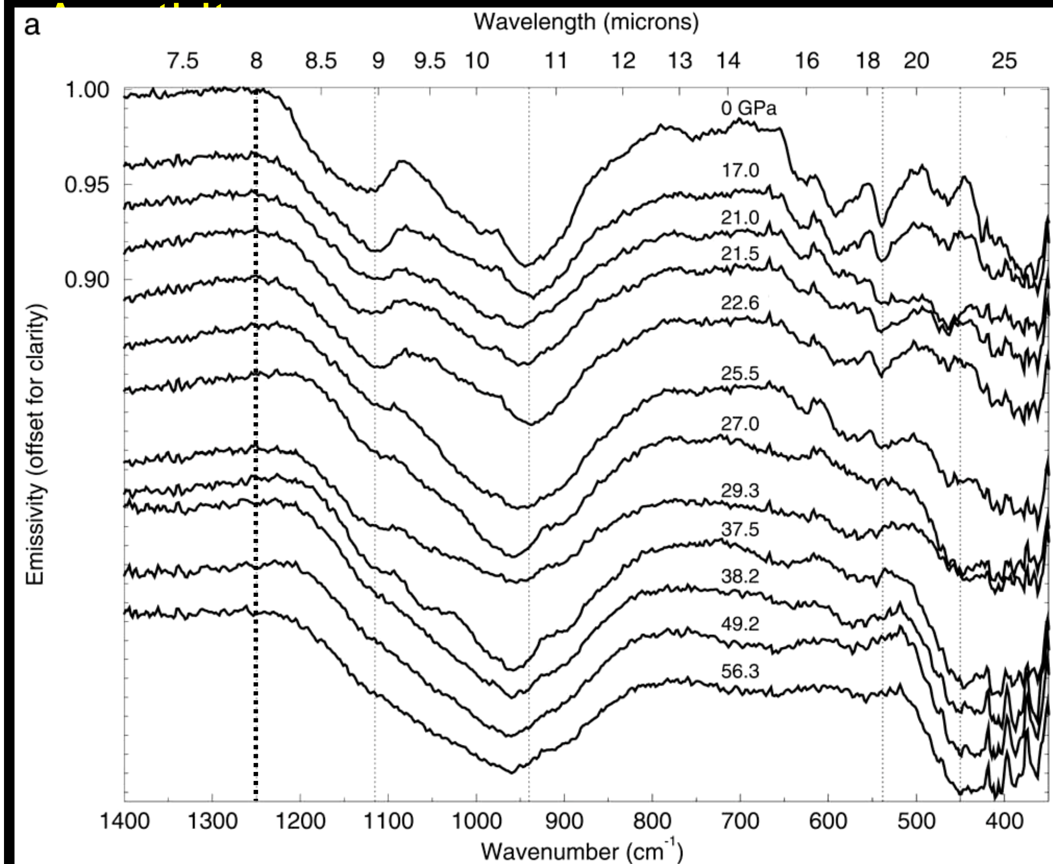
Donaldson Hanna et al., 2010

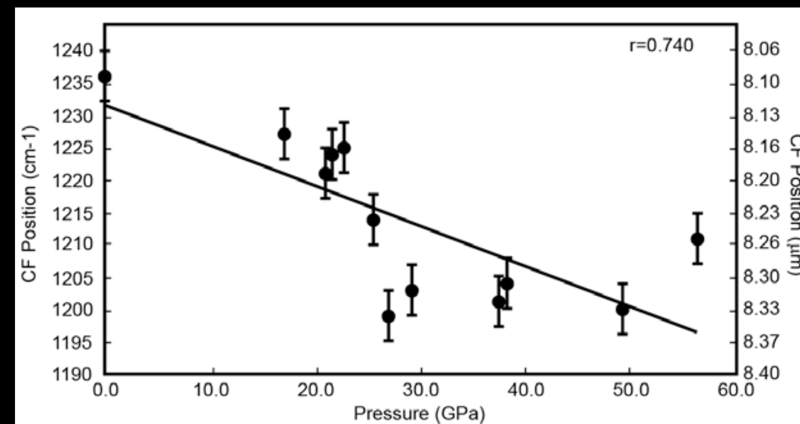
- Diviner band ratios can be used to distinguish mineral groups.

- Diviner band ratios can not be used to distinguish different mineral mixtures.

Background: Application of TIR data for Moon

Influence of Shock Pressures on





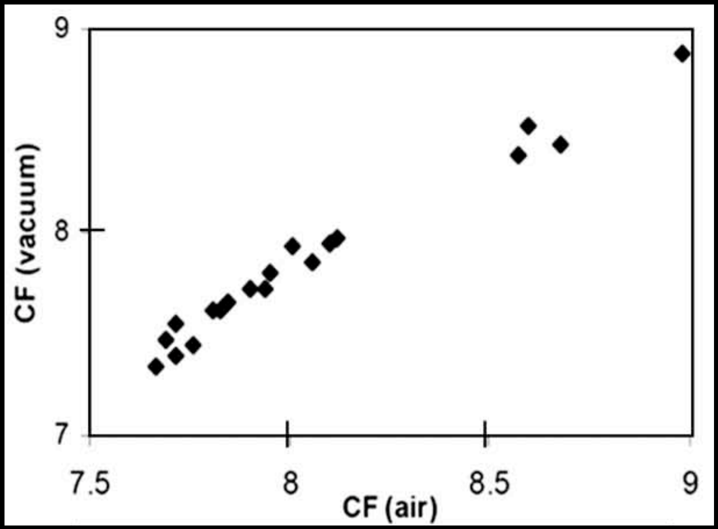
J.R. Johnson et al., 2010

- The Christiansen Feature at ~ 8.0 µm shifts to longer wavelengths with increasing shock pressure.

* Focus of TIR study on crystalline plagioclase as identified by NIR data.

Background: Application of TIR data for Moon

Influence of the
Lunar Environment



- As pressure decreases, spectral contrast increases due to an enhanced thermal gradient, and CF shifts to shorter wavelengths

Logan et al., 1973
Salisbury and Water, 1989

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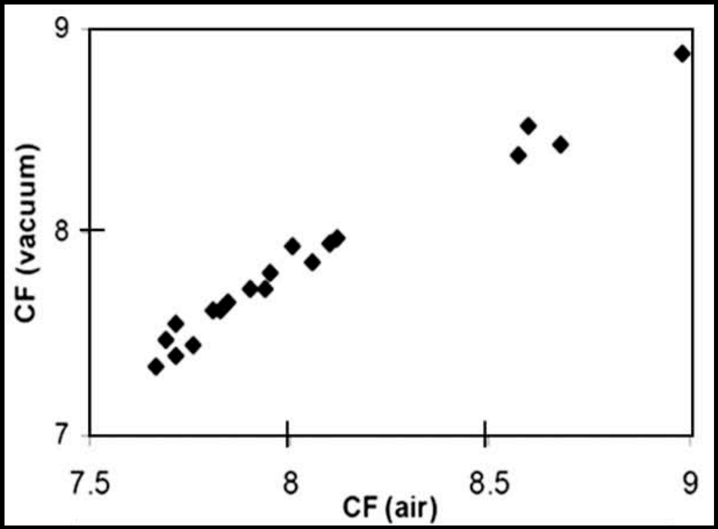

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Logan et al., 1973
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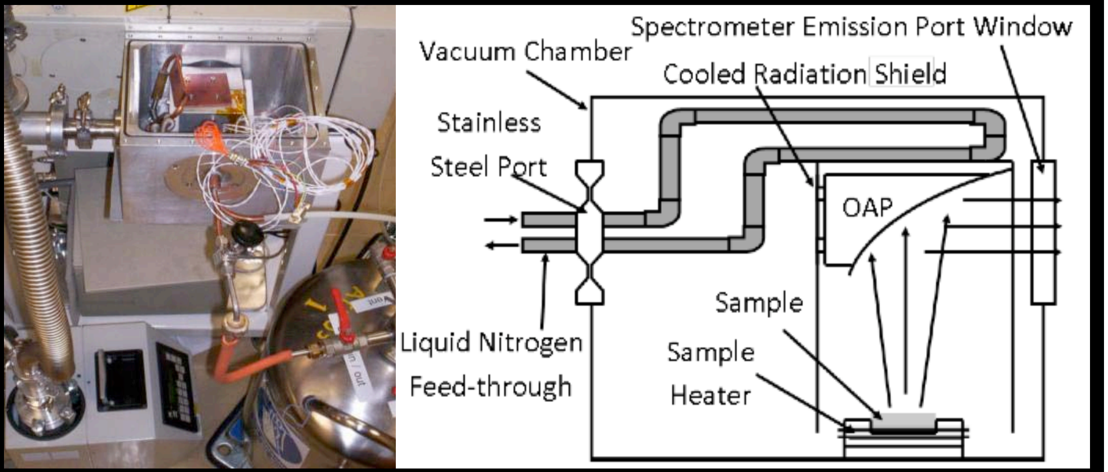
Oxford University
Lunar Environment Chamber



-Well characterized samples of An, Lab, And, Olig, and Ab ground and sieved into 0 - 25 μm and 125 - 250 μm grain size fractions

-Sample heated to 80^{o}C, ambient measurements made under ~1 bar of nitrogen purge, vacuum pressures range between ~1 e^{-4} - 1 e^{-5}

Bowles and Thomas, 2010

Fine-Grained Ambient & Vacuum Measurements

CF Position

	Ambient	Vacuum
An	8.277	7.953
Lab	7.965	7.643
And	7.941	7.626
Olg	7.637	7.207
Ab	7.798	7.537

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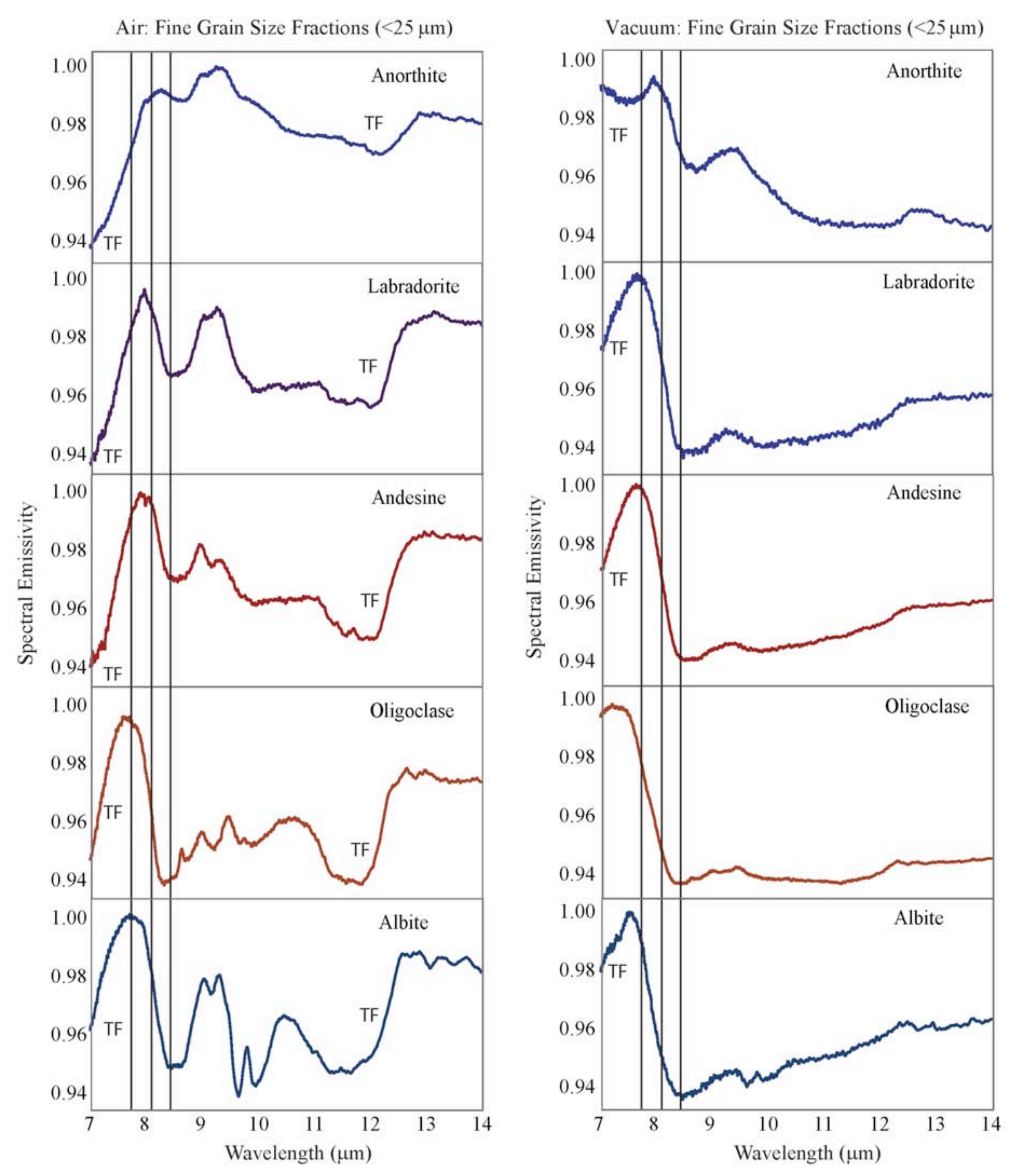

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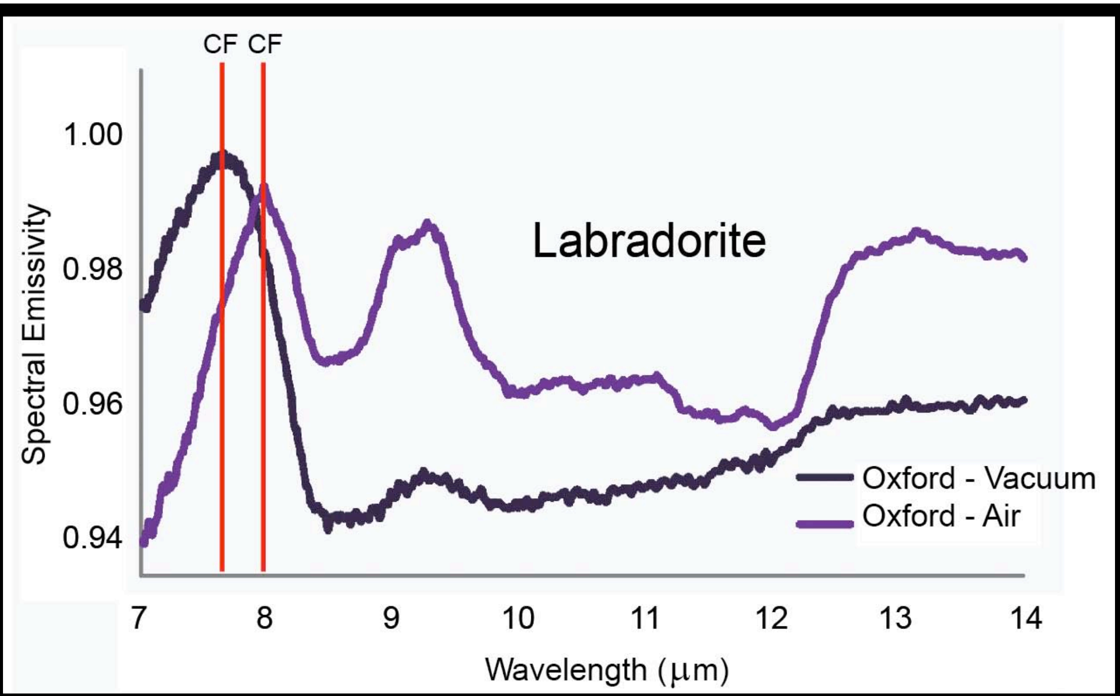

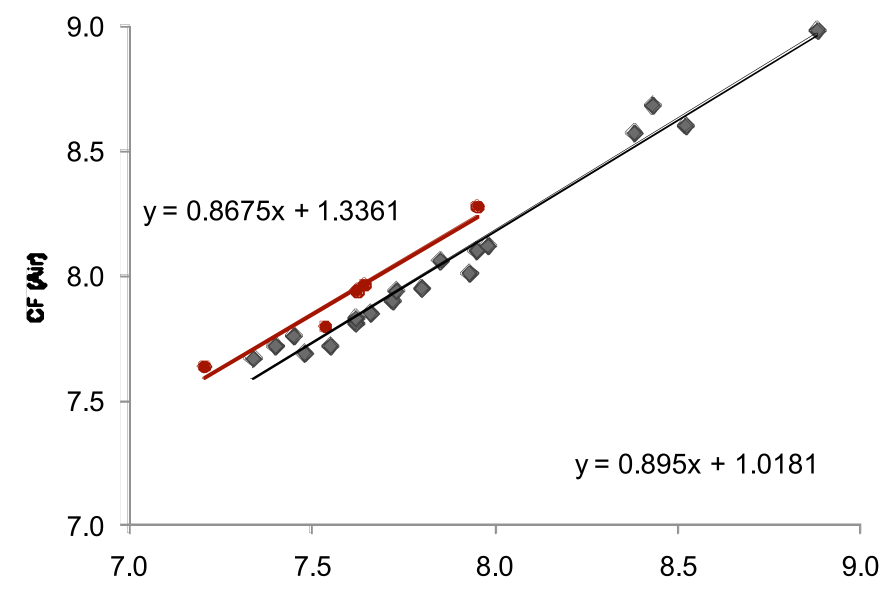

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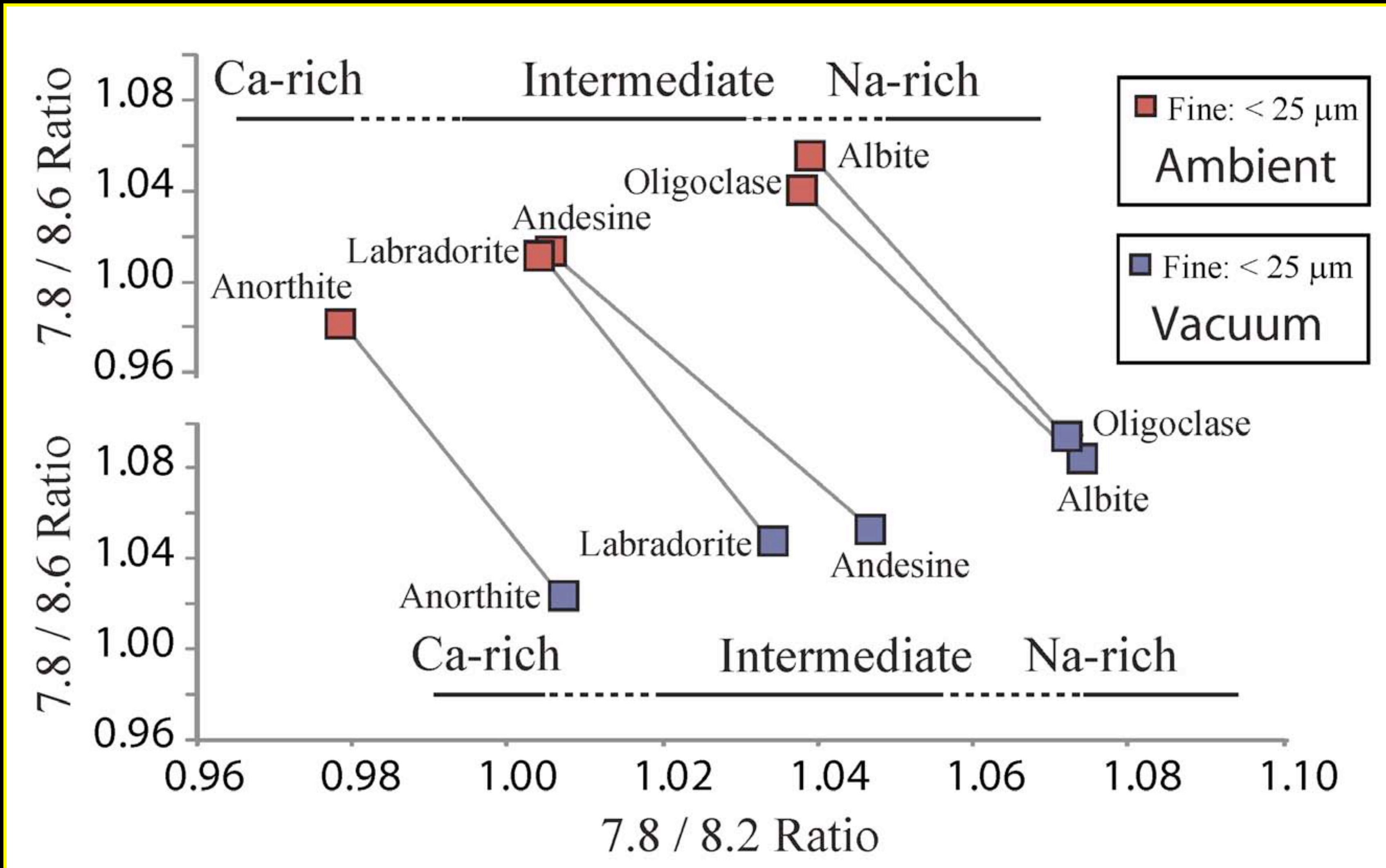
Diviner Ambient & Vacuum Fine Grain Spectra



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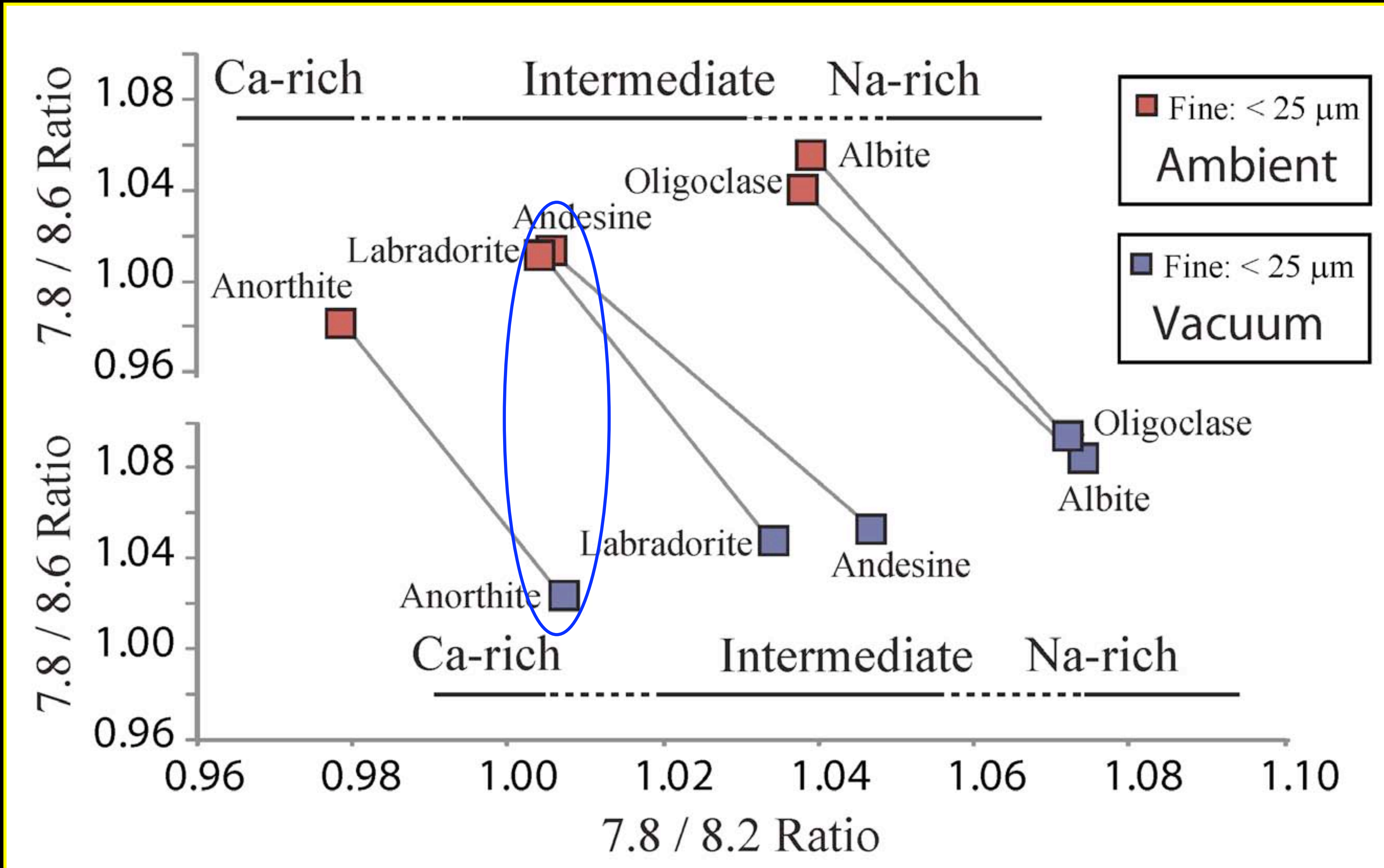
Diviner Ambient & Vacuum Fine Grain Spectra



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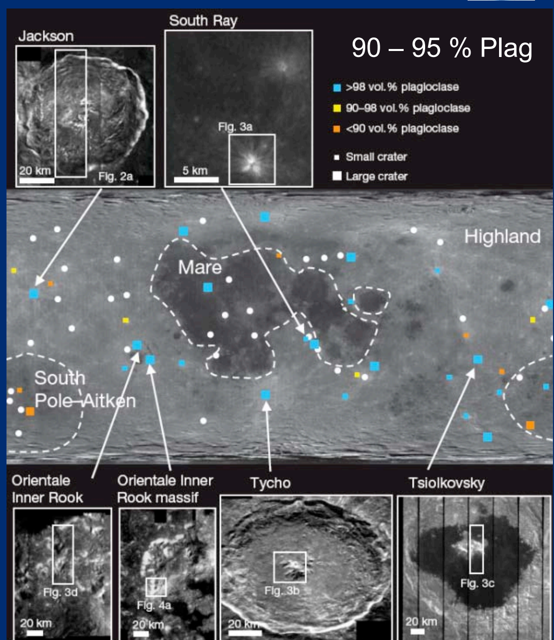
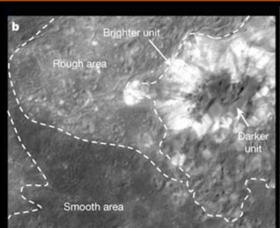
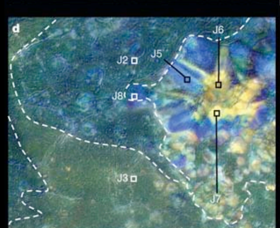
SELENE - SP and MI

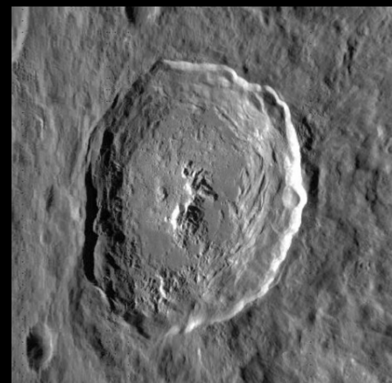


Ohtake et al., 2009





Jackson Crater (71 km diameter)



LROC WAC image

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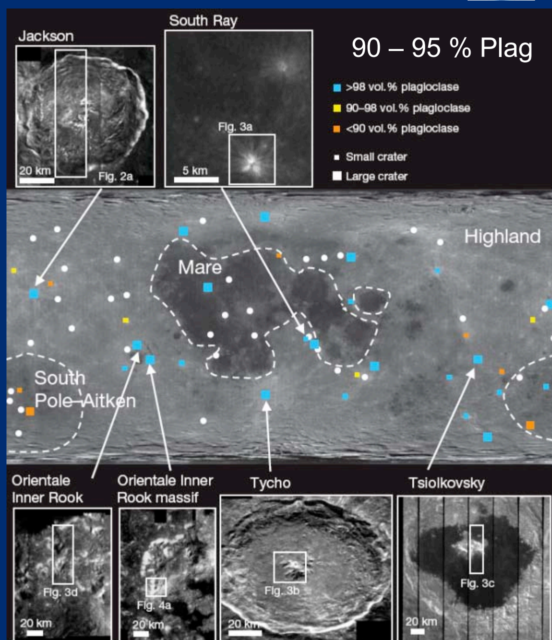

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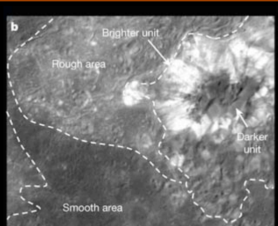

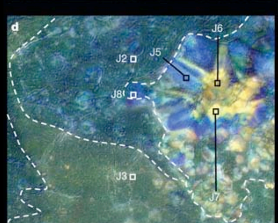

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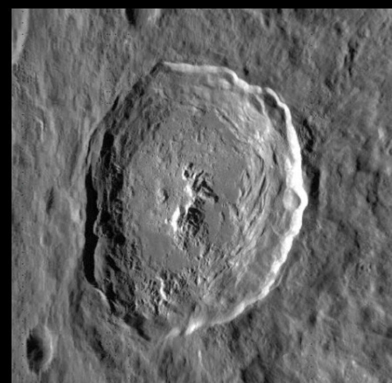
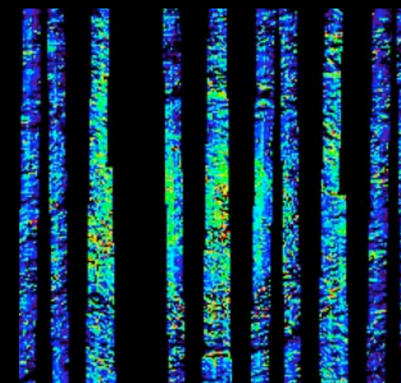


LROC WAC image

Diviner B7 Temp
(297-373 K)



Diviner 7.8/8.25 μm

0.96  1.07

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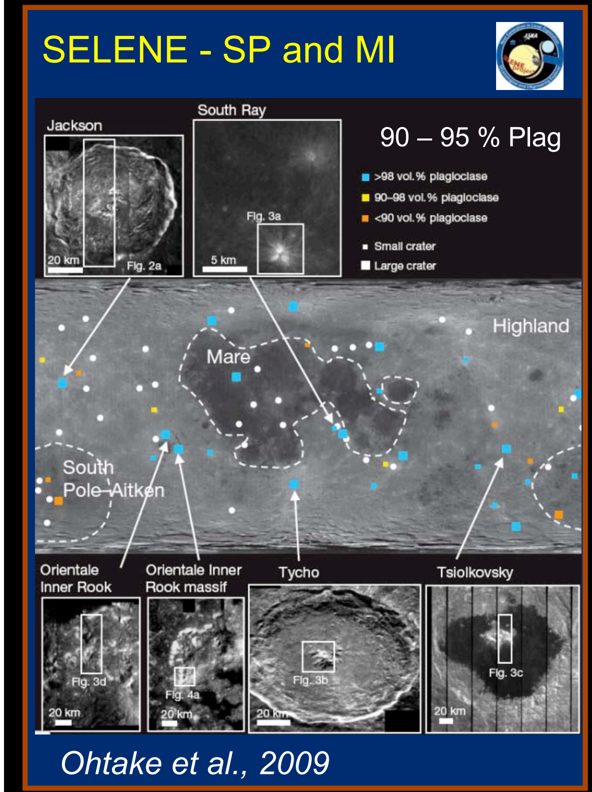

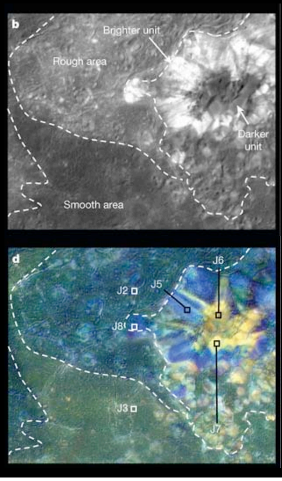

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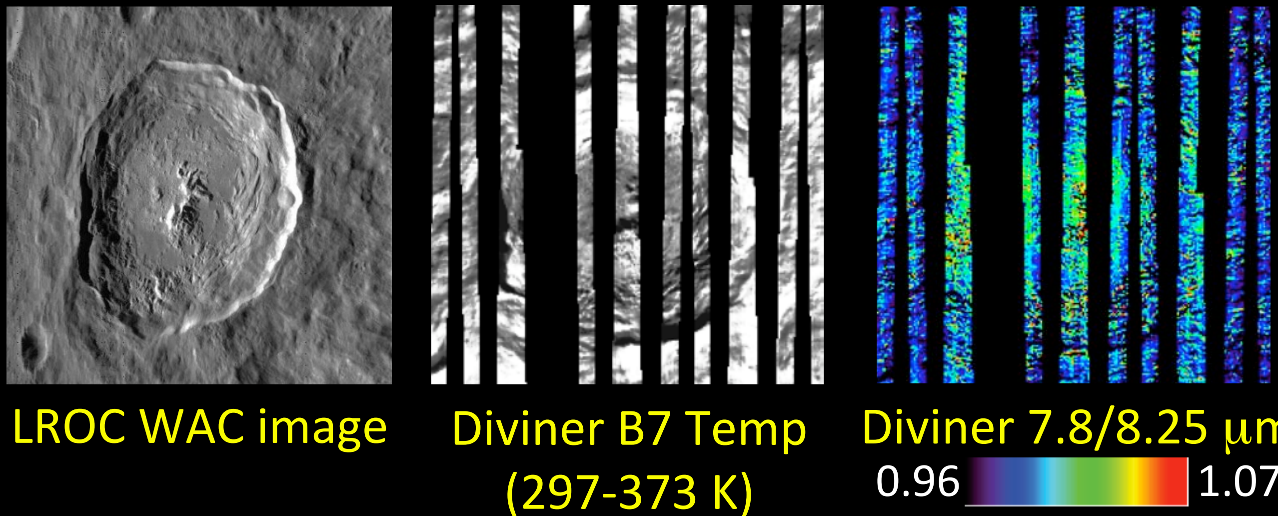

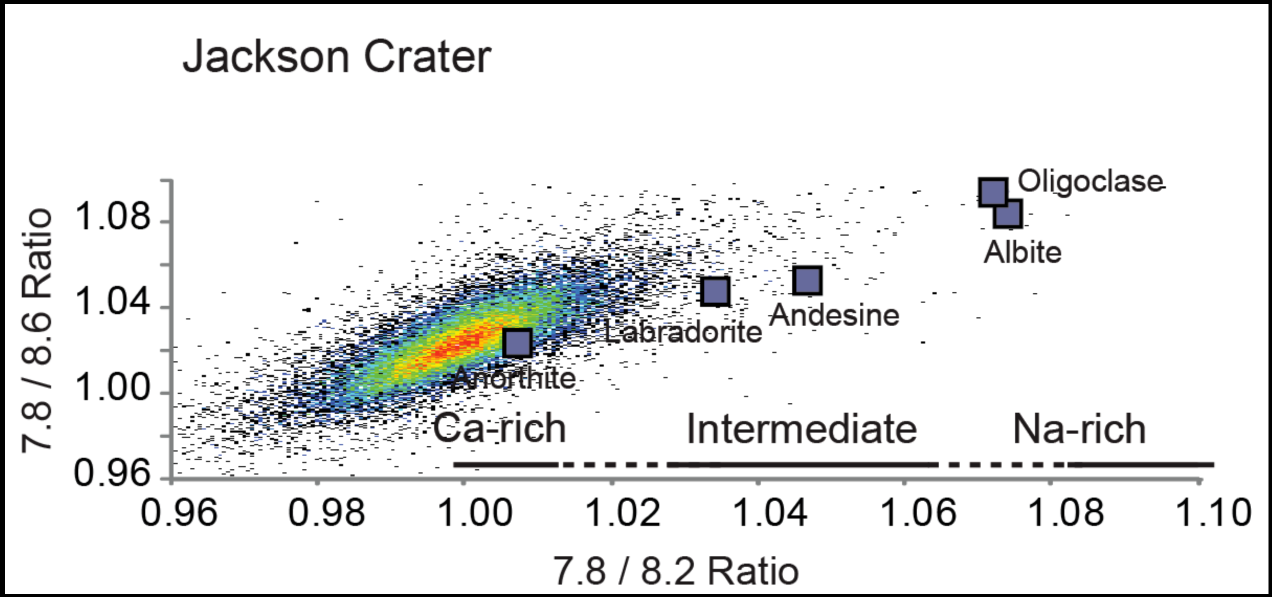

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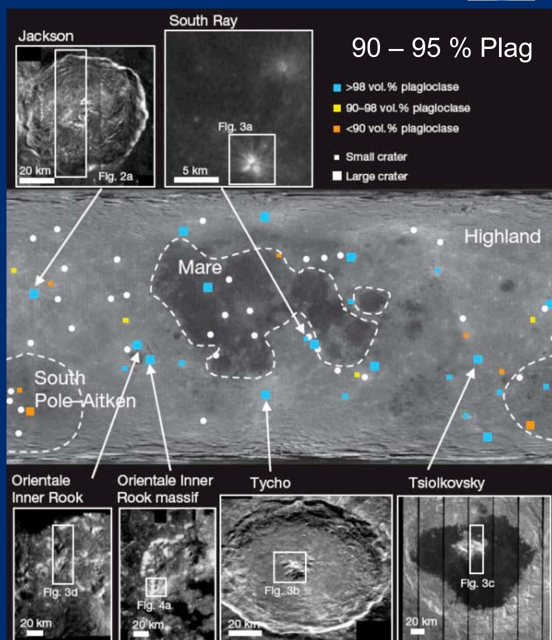
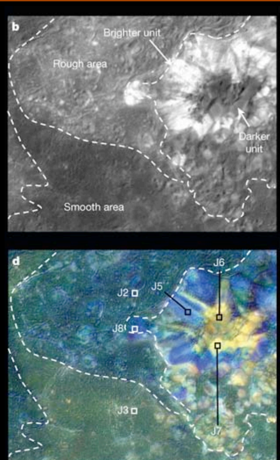


Ohtake et al., 2009



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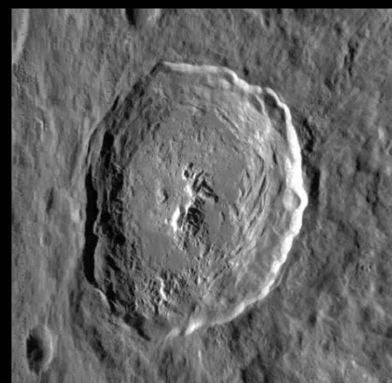

LROC WAC image

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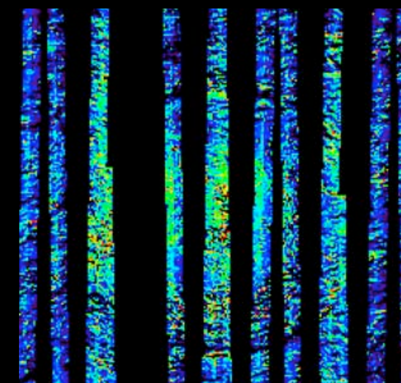

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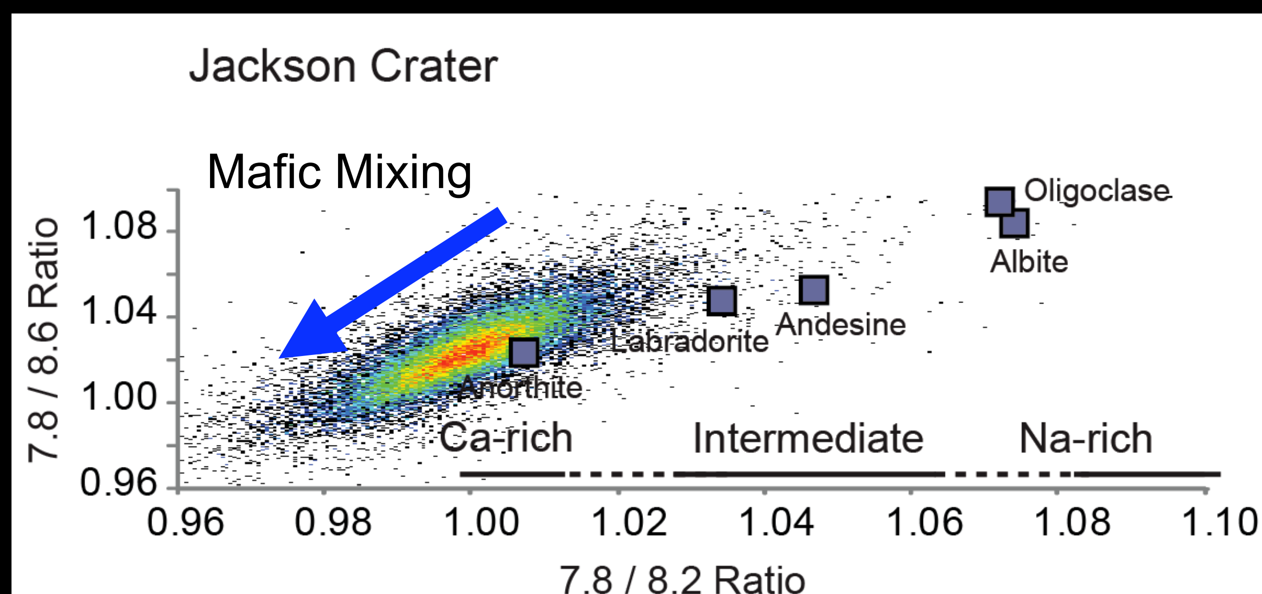

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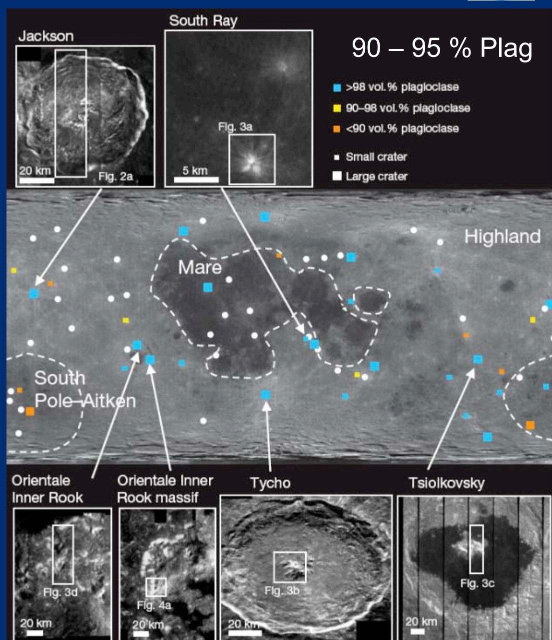

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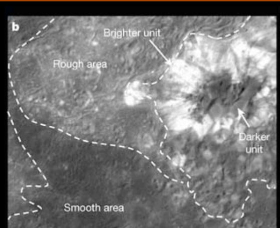

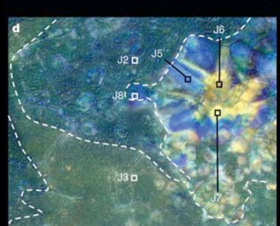

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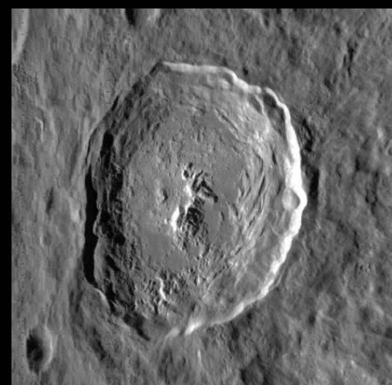

LROC WAC image

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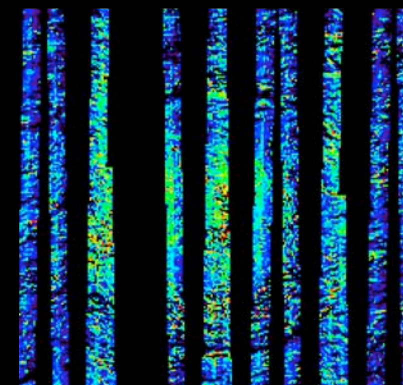

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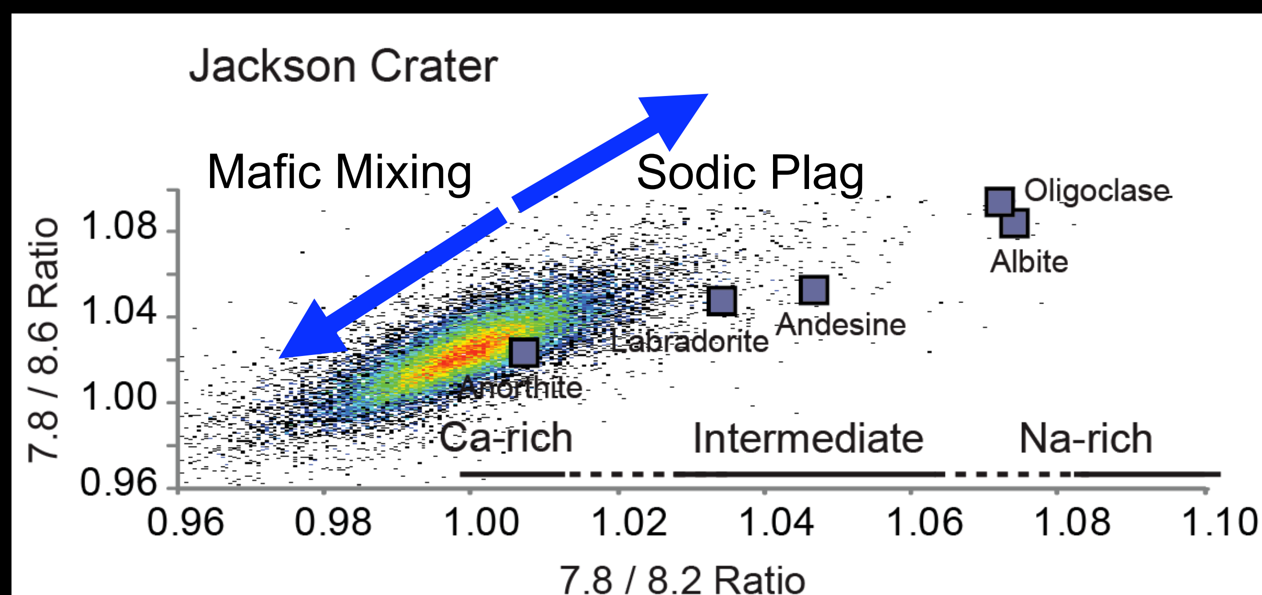

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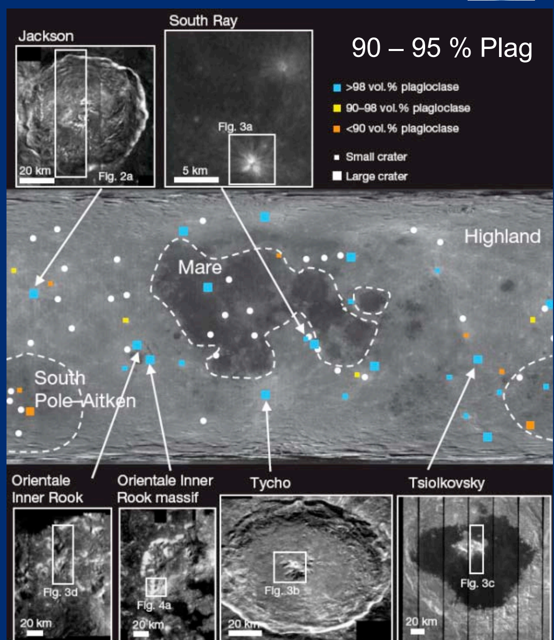

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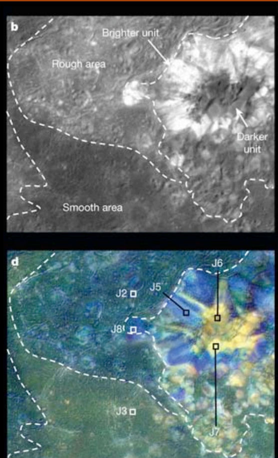

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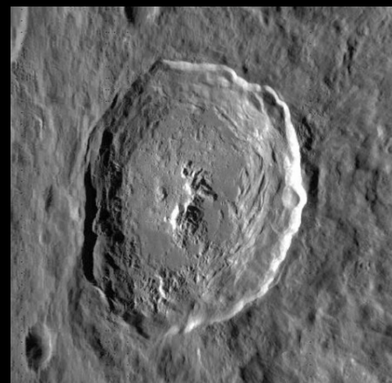

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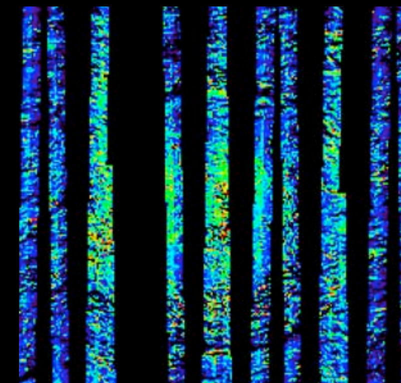
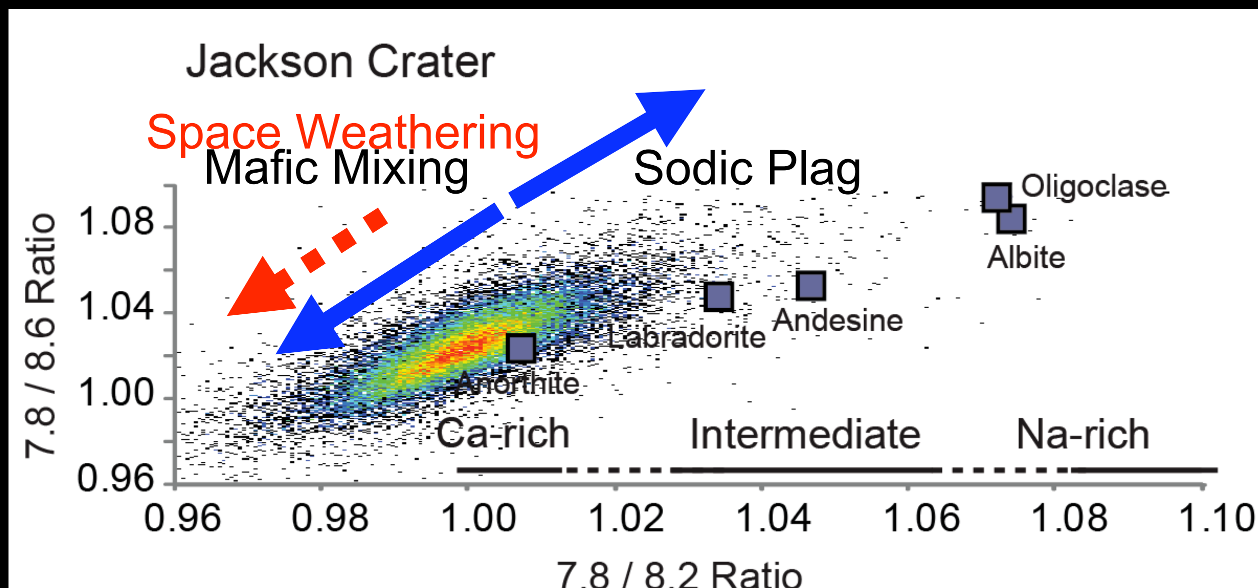
Diviner B7 Temp
(297-373 K)



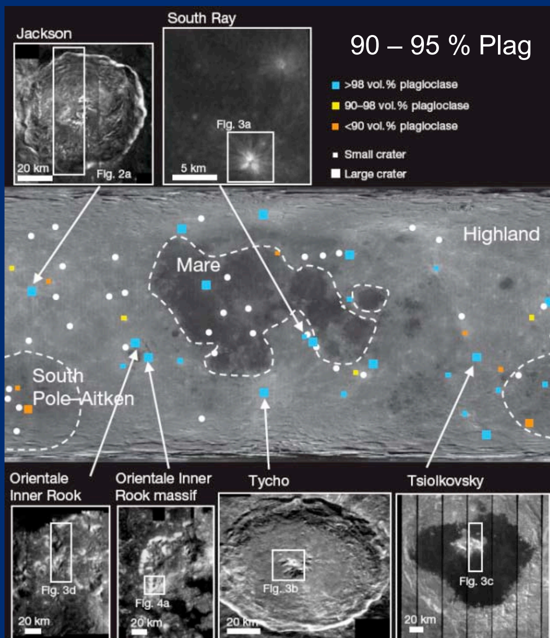
Diviner 7.8/8.25 μm

0.96  1.07

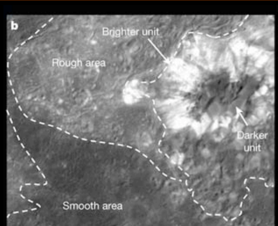


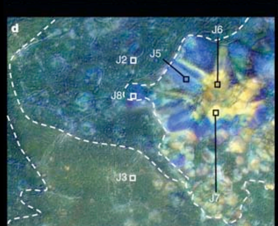
Diviner Observations of Pure Plagioclase Regions

SELENE - SP and MI

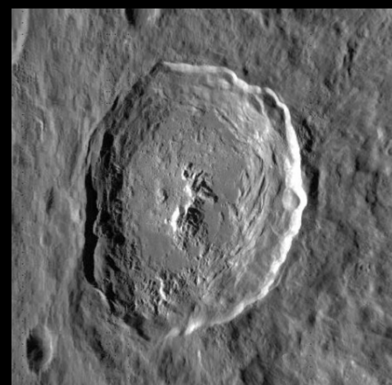


Ohtake et al., 2009



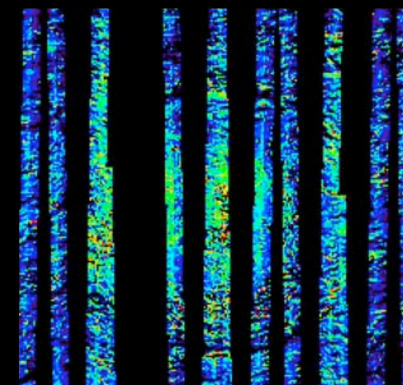


Jackson Crater (71 km diameter)



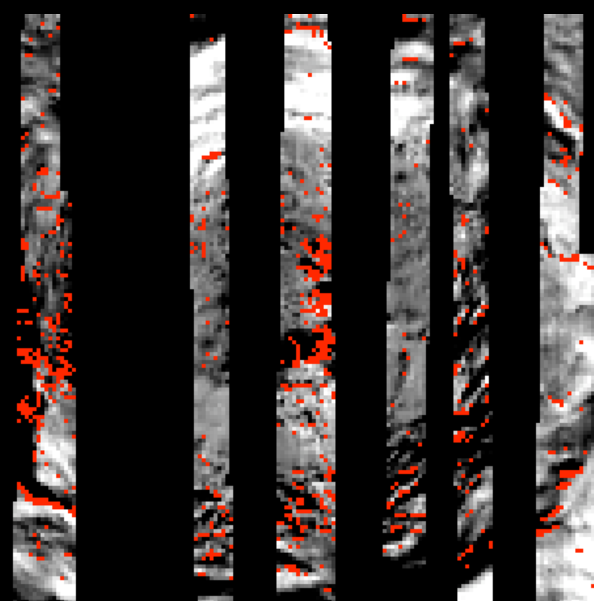
LROC WAC image

Diviner B7 Temp (297-373 K)



Diviner 7.8/8.25 μm

0.96  1.07

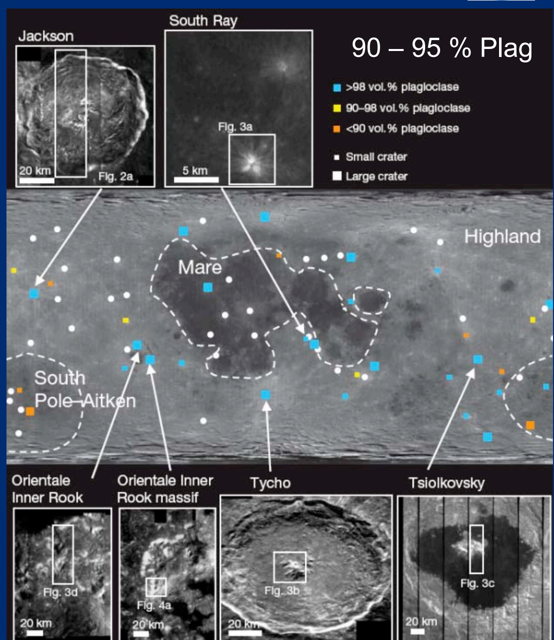


Diviner Band Ratio

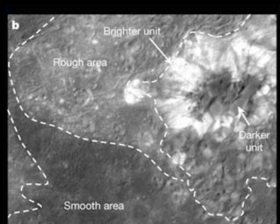
7.8/8.25 μm > 1.02

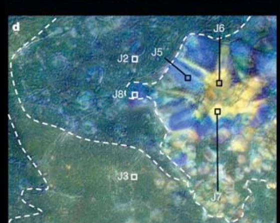
Diviner Observations of Pure Plagioclase Regions

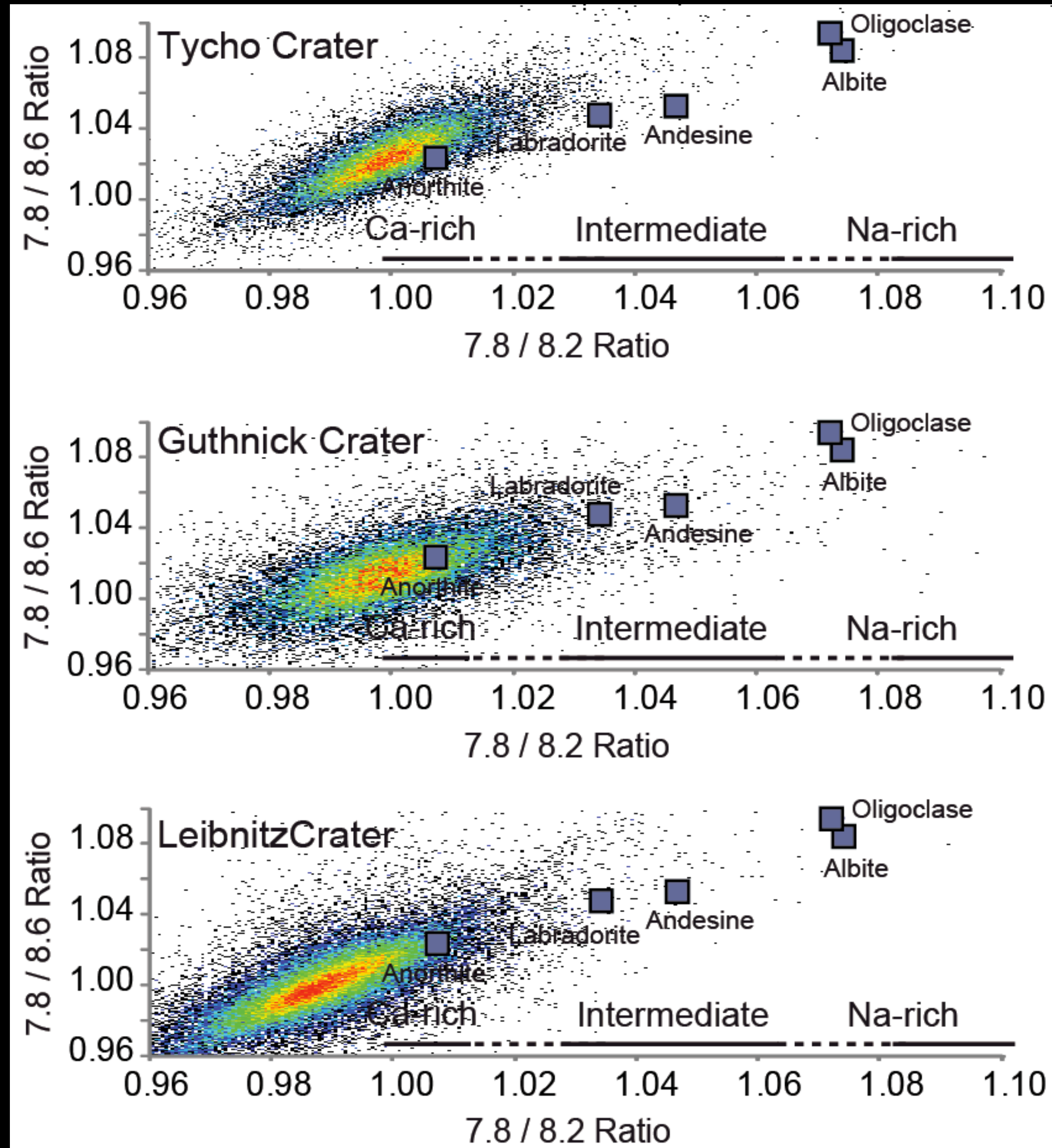
SELENE - SP and MI



Ohtake et al., 2009



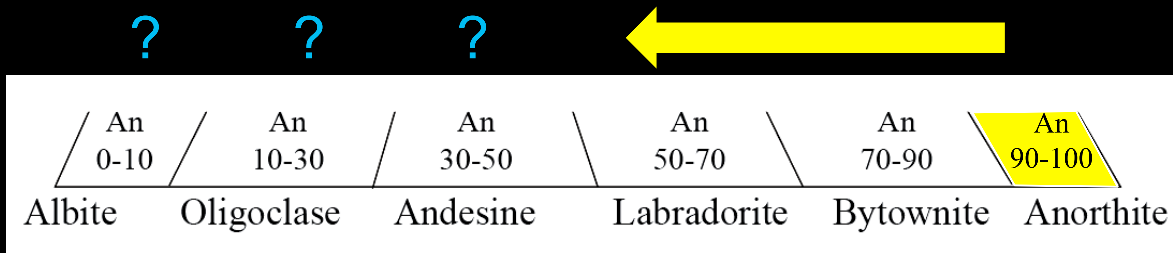


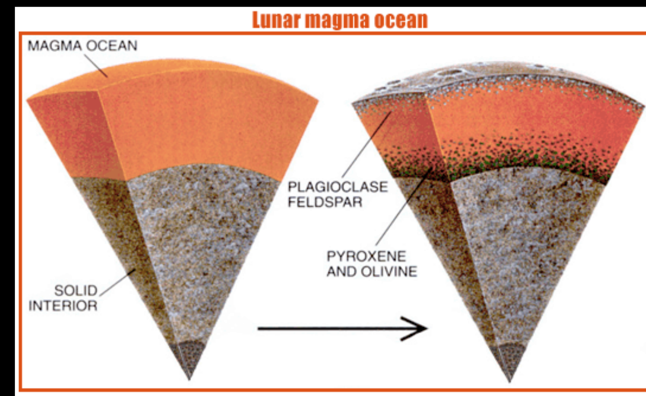


Diviner Plagioclase Conclusions

- New laboratory measurements of the plagioclase solid solution series under lunar environmental conditions confirm the CF shifts to shorter wavelengths.
- New vacuum measurements make it possible to analyze lunar plagioclase compositions (An #) with Diviner data in monomineralic regions.
- While it is not possible to determine exact An # with Diviner band ratios, it is possible to distinguish between Ca-rich, intermediate and Na-rich compositions.
- Preliminary analyses of Diviner data at Jackson, Tycho, Guthnick, and Leibnitz craters identify NIR pure plagioclase regions being consistent with variable plagioclase compositions (An #) as well as regions of plagioclase mixed with some mafic components.

Implications for Lunar Magma Ocean





- On Earth, Anorthosite is divided into two types:

- Proterozoic anorthosite, also known as massif-type anorthosite, have plagioclase compositions typically ranging from An_{40} - An_{60} and are more sodic compared to Archean anorthosite.

-These two types of anorthosite have different modes of occurrence, appear to be restricted to different periods in Earth's history, and are thought to have had different origins.

-Diviner plagioclase compositional mapping may constrain thermal and chemical regional variations in the global lunar magma ocean.